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SENSORY QUALITY, TEXTURAL CHARACTERISTICS AND HYDROXYPROLINE CONTENT OF IRRADIATED BEEFSTEAKS

by
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December 1998

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1977 and 1978

U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND
SOLDIER SYSTEMS CENTER
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This report describes the effect of radiation processing conditions on the quality of beef loin steaks and restructured beef steaks that had been irradiated with two irradiation sources, a linear electron accelerator and a cobalt 60 gamma source. Changes in the sensory properties, shear press values and hydroxyproline content were measured. The restructured steaks were acceptable, but less preferred than the loin steaks. The irradiation dose and processing temperature were shown to affect the quality. In most cases, the electron irradiated steaks were rated higher than the gamma irradiated ones. Texture measurements were significantly affected by both the irradiation temperature and dose. All the irradiated steaks tested in the acceptable range. This indicated that irradiation sterilized beefsteaks can be produced and are useful in military and civilian feeding systems.

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PREFACE

The report describes tests conducted by members of the Irradiated Food Products Group, Radiation Preservation of Food Division, Food Engineering Laboratory, US Army Natick Research and Development Command in 1977 and 1978.

It is being published now as the Army has expressed a need for irradiation sterilized meat products, (Loveridge, 1994). The data is relevant.

The report describes the effect of irradiation processing conditions on the quality of beef loin steaks and restructured steaks that had been irradiated with two sources, an electron linear accelerator and a cobalt 60 (Co^{60}) gamma source. Changes in the sensory properties, shear press values and hydroxyproline content were measured.

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SENSORY QUALITY, TEXTURAL CHARACTERISTICS AND HYDROXYPROLINE CONTENT OF IRRADIATED BEEFSTEAKS

INTRODUCTION

Ionizing radiation has been accepted world-wide as a modern method for sterilizing meat products. The improvement in the quality and storage stability of various meat products has been reported by many investigators (Cain et al. , 1958, Heiligman 1965, Kaufman and Harlan 1969, Shults and Wierbicki, 1974, Shults et al. 1975). A major technological improvement responsible for the increase in the quality of the irradiated products has been the irradiation at sub-zero temperatures. Research at cryogenic temperatures has been reported by many investigators (Coleby et al. 1961, Snyder, 1961, Wadsworth and Shults 1966, Harlan et al. 1967, Kauffman and Harlan 1969, Shults et al. 1974, 1975 and 1977). This research showed that the improvement in quality increases as the product temperatures decrease during irradiation. This was reported for beef, chicken, ham and pork. Harlan et al. (1967) and Shults and Wierbicki (1974) showed that irradiation at -196 ^{o}C yielded a product equal to the nonirradiated item in sensory characteristics.

Shults and Wierbicki (1974) showed that irradiation below -80 ^{o}C did not result in any significant improvement in beef items. Significant differences (improvements) in the quality when the irradiation temperature of the samples was lowered from -40 ^{o}C to -80 ^{o}C. However, Grecz et al. (1971) determined the resistance of Clostridium botulinum spores to ionizing radiation. The authors reported that as the temperature during irradiation was lowered, spore resistance increased; ie., lowering of the temperature of irradiation increases the total dose required to obtain a sterile product. Increasing the dose received by the product results in a lowering of the quality. (Shults et al. 1974, 1975, 1977 and Kauffman and Harlan 1969). Irradiation dose and temperature effects on both the product quality and microbiological factors have to be taken into account when developing irradiation processing technology.

A recent development in the meat industry has been the introduction of restructured meats into the institutional trade and for home use. Cost of fresh meats has been increasing and restructured meat items, i.e., steaks, chops and roasts, offer the technology to produce products from lower costing meat cuts without a reduction in the nutritional and sensory quality (Mandigo 1974, Cross and Stanfield 1976). Heiligman et al. (1976) reported that restructured irradiated beef rolls were acceptable after 15 months storage, but textural characteristics were affected by the irradiation processing. Cohen et al. (1974) also reported that irradiation lowered shear press values and sensory ratings by trained panelists.

This study was initiated to determine the effects of irradiation processing conditions on the quality of beef loin steaks and restructured steaks. The steaks were irradiated with two sources, an electron linear accelerator and a gamma source, Co^{60}. Changes in the sensory properties, shear press values and hydroxyproline were measured.

Materials and Methods

Loin Steak

Fresh, USDA choice grade loin muscles, Longissimus, 5-7 days post-mortem, were trimmed of all surface fat. The loin muscles were pumped with a solution of sodium chloride and sodium tripolyphosphate (TPP) to yield the added concentration of 0.75% and 0.30%, respectively. The pumped loins were held overnight at +2 to +5 ^{o}C and

then sliced into 13 mm thick steaks. The steaks were enzyme inactivated on a grill (227 °C) to an internal temperature of 72 to 75 °C.

Restructured Steak

Fresh USDA choice grade whole rounds (with shanks removed), 5 - 7 days post mortem, were trimmed of all surface fat, individual muscles sectioned and defatted. The meat was cut into 20 - 100 g chunks and mixed with 0.75% sodium chloride, 0.3% sodium TPP and 3.0% chipped ice in a Hobart™ mixer for 20 minutes. After mixing, the meat was formed in metal wire cages, 88 x 127 mm, cross section and tempered to -5 °C. The meat block was cut into 120 g steaks, which were enzyme inactivated on a 227 ° C grill to an internal temperature of 72 to 75 °C.

Packaging

The cooked steaks were packaged in multilayer flexible pouches (114 x 192 mm) and sealed under vacuum on a Multivac™ Heat Sealer. The food contact layer was high density polyethylene (HDPE). After closure the pouches were held at the desired processing temperature until irradiation.

Irradiation Processing

Irradiation of the product was carried out in the radiation facilities at the US Army, Research and Development Command, Natick, MA. Samples were given total dose of 18.5, 37 and 74 kGy with a dose range of ± 9%. Irradiation temperatures were +5, -30 and -80 ± 10 °C for gamma irradiation. Samples irradiated with the electron source were packed in insulated containers without temperature control during processing. Temperatures increased by 15 to 25 °C during irradiation. For shear press and hydroxyproline analysis, the samples were also irradiated at 148 kGy. The dose rate of the gamma source was 14 Gy/kg/sec. The linear accelerator utilizes 10 Mev electrons and a dose rate of 10^9 kGy per second. Samples were stored at 21 ± 2 °C after irradiation. Nonirradiated frozen controls were held at -29 °C.

Evaluation

The samples were evaluated by 10 - 12 member sensory panels for the sensory characteristics: Odor, flavor, color and texture in which the following scale was used: 1 - extremely poor; 2 - very poor; 3 - poor; 4 - below fair, above poor; 5 - fair; 6 - below good, above fair; 7 - good; 8 - very good; 9 - excellent.

Preference ratings were obtained by 30 - 36 member consumer panels. Evaluations for preference were made using the scale of one to nine, with one being "dislike extremely" and nine meaning "like extremely" (Peryam and Pilgrim, 1957). A rating of 5, "neither like nor dislike" is considered the base line in determining the acceptability of the product. Samples were warmed to a 60 °C internal temperature in electric ovens at 165 °C and served individually to the panelists.

Statistical Analysis

All of the data reported in this paper were subjected to statistical analysis using analysis of variance and least significant differences methods (Steel and Torrie, 1960).

Texture Determination (Shear Press)

Shear press analyses were determined on a Kramer™ Shear Press. The method

was similar to that described by Cohen et al., 1974. A 25 x 50 x 12.5 mm meat sample was used for each reading. Each sample was replicated 16 times and the results reported in newtons.

Results and Discussion

The effects of irradiation temperature on loin steaks irradiated with electron and gamma sources are shown in Table 1. Significant differences were found between the flavor ratings of the electron irradiated samples, but these differences could not be associated with the temperatures of irradiation. No significant differences in the sensory ratings were found in the gamma irradiated samples.

Table 1 - Effect of Irradiation Temperature on Quality of Loin Steaks

Temp.	Sensory Characteristics							
	Color		Odor		Flavor		Texture	
°C	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A. Electron Source								
+5	7.3	0.6	6.8	1.1	$6.5^{a,b}$	1.3	6.9	1.0
-30	7 .6	0.8	6.8	0.6	$7.0^{b,c}$	0.9	7.2	1.2
-80	7.0	1.0	6.4	1.4	5.9^{a}	1.6	6.4	1.1
control	7.8	0.8	7.4	0.9	7.6^{c}	1.0	7.3	1.1
F	0.2		1.5		3.2		1.2	
significance	NSD		NSD		0.05		NSD	
LSD (0.05)	NA		NA		1.16		NA	
B. Gamma Source								
+5	7.3	0.8	6.9	0.9	6.7	1.4	6.9	1.0
-30	7.4	0.7	6.8	1.1	6.5	1.1	6.8	0.9
-80	7.5	0.7	7.0	0.8	6.8	1.0	7.2	0.8
control	7.1	0.9	7.3	0.8	7.6	1.0	7.2	1.0
F	0.4		0.5		1.7		0.5	
significance	NSD		NSD		NSD		NSD	
LSD (0.05)	NA		NA		NA		NA	

Means in a column followed by the same latter are not significantly different.
Irradiation conditions - 37 kGy dose. Irradiation temperature variation - ± 10 °C
10 panelists per test

Temperature effects for restructured steak are shown in Table 2. Flavor ratings for both the electron and gamma irradiated samples were significant. When the processing temperature decreased, the flavor scores significantly increased. In most cases, samples irradiated at +5°C were rated lower than sample irradiated while frozen. The ratings for all the samples were in the acceptable range. Small differences within the samples were not detected due to the grilling of the steaks. The "grilled" flavor of the steaks masked the changes in the odor and flavor that were due to irradiation processing.

Table 2 - Effect of Irradiation Temperature on Quality of Restructured Steaks

Temp.	Sensory Characteristics							
	Color		Odor		Flavor		Texture	
°C	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A. Electron Source								
+5	6.8	1.1	6.0	1.6	5.4[a]	1.4	5.5	1.7
-30	6.4	0.9	6.3	1.0	5.9[a,b]	0.8	6.1	1.0
-80	6.8	1.0	6.3	1.2	6.5[b,c]	1.1	6.7	1.0
control	7.3	1.0	6.8	1.2	7.1[c]	0.9	6.7	1.0
F	1.2		0.6		4.0		1.4	
significance	NSD		NSD		0.05		NSD	
LSD (0.05)	NA		NA		1.05		NA	
B. Gamma Source								
+5	6.6	1.0	5.3	1.5	5.0	1.0	5.9[d]	0.9
-30	7.0	1.0	6.8[a,b]	1.2	6.6[c]	1.3	6.5[d.e]	1.0
-80	7.2	0.6	6.4[a,b]	0.5	6.5[c]	0.8	6.6[d,e]	1.0
control	7.3	0.9	7.5[b]	0.7	6,6	0.7	7.3[e]	0.6
F	1.1		7.2		11.1		3.5	
significance	NSD		0.01		0.01		0.05	
LSD (0.05)	NA		1.0		0.9		0.9	
LSD (0.01)	NA		1.32		1.34		NA	

Means in a column followed by the same letter are not significantly different

Irradiation conditions - 37 kGy dose, temperature variation ± 10 °C

10 panelists per test

The effects of irradiation dose on loin steaks are listed in Table 3. Differences between the samples irradiated at the three dose levels were not significant and no trends were established that were associated with the dose levels.

Table 3 - Effect of Irradiation Dose on the Quality of Loin Steaks

Dose kGy	Sensory Characteristics: Color Mean	Color SD	Odor Mean	Odor SD	Flavor Mean	Flavor SD	Texture Mean	Texture SD
A. Electron Source								
18.5	6.8	1.0	6.0[a]	1.2	5.9[b]	1.3	6.8	1.1
37.0	6.6	0.8	6.0[a]	0.6	6.3[b]	0.9	6.6	0.9
74.0	6.6	1.1	5.9[a]	1.0	5.6[b]	1.4	6.1	1.1
control	7.4	0.9	7.7	0.5	7.7	0.6	7.2	1.6
F	1.4		8.8		6.5		1.3	
significance	NSD		O.01		0.01		NSD	
LSD (0.05)	NA		0.8		1.0		NA	
LSD (0.01)	NA		1.1		1.4		NA	
B. Gamma Source								
18.5	6.7	1.0	5.4	1.6	5.3[a]	1.8	6.3[c,d]	0.8
37.0	7.2	0.8	6.1	1.1	6.4[a,b]	0.9	7.3	0.8
74.0	6.8	1.1	6.2	1.2	5.3[a]	1.9	5.6[d]	2.0
control	7.2	0.9	6.9	1.4	7.5[b]	0.7	7.0[c]	1.1
F	2.14		1.94		4.92		3.32	
significance	NSD		NSD		0.05		0.05	
LSD (0.05)	NA		NA		1.4		1.2	
LSD (0.01)	NA		NA		1,8		NA	

Means in a column followed by the same letter are not significantly different
10 panelists per test

-30 $\pm 10^{o}C$ irradiation temperature

Sensory scores for the restructured steaks are shown in Table 4. The conclusions were similar to the loin steak results. No statistical differences were determined in the electron processed group. For the gama processed group, irradiation at 754 kGy resulted in a lowering of the sensory values. For both flavor and texture, a signficant reduction in sensory ratings was found

Table 4 - Effect of Irradiation Dose on Quality of Restructured Steaks

Dose kGy	Sensory Characteristics: Color Mean	Color SD	Odor Mean	Odor SD	Flavor Mean	Flavor SD	Texture Mean	Texture SD
A. Electron Source								
18.5	7.1	0.9	7.0	0.9	6.8	0.8	7.0	0.8
37.0	7.1	0.8	6.5	1.0	6.4	1.3	6.5	0.9
74.0	7.4	0.9	6.9	0.5	6.6	0.9	6.0	1.9
control	7.4	0.7	7.1	1.0	7.4	0.8	7.3	0.6
F	0.4		0.8		1.8		2.2	
significance	NSD		NSD		NSD		NSD	
LSD	NA		NA		NA		NA	
B. Gamma Source								
18.5	7.3	0.8	6.8	1.0	6.9[a]	1.5	7.6	0.8
37.0	6.9	0.9	6.7	1.0	6.6[a]	1.3	6.9[b]	1.0
74.0	6.8	0.6	5.8	1.3	4.9	1.3	5.9[b]	1.7
control	7.0	0.9	6.6	0.9	7.1[a]	1.0	6.6[b]	1.3
F	0.6		1.7		5.6		2,7	
significance	NSD		NSD		0.01		0.05	
LSD (0.05)	NA		NA		1.2		1.2	
LSD (0.01)	NA		NA		1.6		NA	

The muscle loin and restructured steaks are compared in Table 5. The loin steaks rated slightly better. The electron iradiated steaks rated slightly higher for color and odor (but not significantly) than the gamma irradiated steaks.

Table 5 - Effect of Manufacturing Technique and Irradiation Dose on Quality of Loin Steaks

	Sensory Characteristics								
	Color		Odor		Flavor		Texture		Irradiation
Technique	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Source
Restructured	6.6[a]	0.5	5.9[c,d]	0.8	5.6[e]	0.8	5.9	1.1	electron
Restructured	5.8	1.4	5.3[d]	1.4	5.3[e]	1.3	5.8	1.5	gamma
Loin Steak	7.0[a]	0.6	6.5[b,c]	0.7	6.1[e]	1.0	6.5	1.1	electron
Loin Steak	6.7[a]	1.0	5.9[c,d]	1.8	5.7[e]	1.9	6.2	1.1	gamma
Loin Steak	7.2[a]	0.6	7.2[b]	0.6	7.6	0.7	7.1	0.8	control
F	3.3		3.6		5.2		1.9		
significance	0.05		0.05		0.05		NSD		
LSD (0.05)	0.9		1.1		1.1		NA		

Irradiation conditions: 37 kGy at -30 ± 10 °C
Means in a column followed by the same letter are not significantly different

The samples were tested after 15 months of storage at 21 °C. The frozen controls were held at -29 °C. Table 6 lists the results of the panel evaluation of the samples irradiated at the various temperatures. No significant differences were found in the electron irradiated group. The scores appear to increase with the lowering of the temperature. In the gamma irradiated group, the same trends were noted. Irradiation at -80 °C resulted in a product which was similar to the nonirradiated frozen control after 15 months of storage.

Table 6 - Effect of Irradiation Temperature on Quality of Loin Steaks After 15 Months of Storage

Irrad. Temp.	Sensory Characteristics							
	Color		Odor		Flavor		Texture	
°C	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A. Electron Source								
+5	7.2	1.1	6.4	1.6	6.0	1.6	6.8	1.4
-30	7.5	1.1	6.8	1.6	6.5	1.6	7.0	1.4
-80	7.8	0.8	6.9	1.5	6.8	1.4	7.5	0.9
control	7.8	0.8	7.2	1.4	7.6	1.1	7.6	1.1
F	0.8		0.4		1.9		0.9	
significance	NSD		NSD		NSD		NSD	
B. Gamma Source								
+5	6.9[a]	0.7	5.7[c]	1.2	5.0[d]	1.3	5.5[f]	1.4
-30	6.7[a,b]	0.8	5.6[c]	1.4	5.0[d]	2.0	6.5[f,g]	0.9
-80	7.3[b]	0.5	6.5[c]	1.2	6.4[d,e]	1.4	6.5[f,g]	1.0
control	6.5[a]	0.5	7.4	1.0	7.6[e]	0.5	7.3[g]	0.8
F	3.1		4.2		8.0		1.0	
significance	0.05		0.05		0.05		NSD	
LSD (0.05)	0.59	1.16	1.25	NA	1.25	NA	NSD	NA

Irradiation Dose: 37 kGy
Means in a column followed by the same letter are not significantly different

The effects of dose are shown in Table 7 . They indicate at all samples were rated in the acceptable range and irradiated samples were equal in quality to the nonirradiated frozen contol

Table 7 - Effect of Irradiation Dose on Quality of Loin Steaks after 15 Months of Storage

Dose kGy	Sensory Characteristics: Color Mean	Color SD	Odor Mean	Odor SD	Flavor Mean	Flavor SD	Texture Mean	Texture SD
A. Electron Source								
18.5	7.3	1.0	7.0	1.2	6.8	1.0	7.4	1.0
37.0	7.4	1.0	7.3	1.3	6.8	1.6	7.9	0.7
74.0	7.2	0.9	6.6	1.4	6.6	1.2	7.1	1.1
control	7.5	0.8	7.1	1.0	7.2	1.3	7.1	0.9
F	0.2		0.5		0.3		1.4	
significance	NSD		NSD		NSD		NSD	
B. Gamma Source								
18.5	7.7	0.9	7.4	1.1	6.5	1.7	7.0	1.3
37.0	7.7	0.9	6.8	1.5	6.5	1.6	7.3	1.3
74.0	7.5	1.0	6.8	1.7	5.8	1.9	6.3	1.6
control	8.1	0.8	7.9	0.9	7.8	1.2	7.9	0.8
F	0.7		1.4		2.4		2.5	
significance	NSD		NSD		NSD		NSD	

Irradiation Temperature: -30 $\pm$10 ^{o} C

Comparison of the sensory characteristics of the irradiated loin andrestructured steaks did not show signficant differences between the samples after 15 months of storage. This is shown in Table 8. Ratings from a 35 member consumer panel showed that the loin samples were preferred to the restructured steaks. There were no signficant differences due to the irradiation source or compared to the control.

Table 8 - Effect of Method of Manufacture and Type of Irradiation on Sensory Characteristics After 15 Months of Storage

Sample Description	Sensory Panel								Consumer Panel Preference	
	Color		Odor		Flavor		Texture			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Restructured Electron	6.4	1.0	5.8	1.4	5.8	1.4	6.6	1.2	5.3[a]	1.7
Restructured Gamma	7.2	0.9	7.2	1.0	7.5	0.8	7.4	0.8	5.8[a,c]	1.5
Loin Steak Electron	6.9	0.9	6.3	1.3	6.2	1.3	6.5	1.4	6.5[b]	1.6
Loin Steak Gamma	6.8	1.5	6.1	1.6	6.4	1.2	6.6	1.1	6.3[b,c]	1.6
Frozen Control Loin	7.0	1.0	6.6	1.2	6.7	1.6	6.9	1.1	6.3[b,c]	1.4
F	0.7		1.5		2,3		0.9		5.4	
significance	NSD		NSD		NSD		NSD		(0.01)	

Means in a column followed by the same letter are not significantly different

Irradiation Dose: 37 kGy Irradiation Temp.: -30 ± 10°C
Sensory Panel - 10 Panelists
Consumer Panel - 35 Panelists

Shear press analyses were determined using an All-Kramer™ Shear Press. Data in Figures 1 and 2 express the shear force in Newtons. It is shown as a function of irradiation dose in Figure 1A and irradiation temperature in Figure 1B for the beef loins. For restructured beef steaks the values are shown as a function of dose in Figure 2A and irradiation temperature in Figure 2B. The dose effect was signficant. Decreasing the irradiation temperature increased the shear values. No significant differences were found between the types of irradiation. At all irradiiation levels the shear values were significantly different between nonirradiated frozen controls and irradiated samples.

The overall results of this study have shown that restructured steaks are acceptable, but less preferred than loin steaks. Irradiation dose and temperature were again shown to affect the quality and in most cases electron irradiated steaks were rated higher than gamma irradiated. Texture measurement was significantly affected by both temperature and dose. All irradiated steak samples tested were found to be in the acceptable range indicating that the irradiation sterilized steaks can be produced and could be useful in military and civilian feeding systems.

Irradiated loin steaks were included in the rations of the joint Russian American (Apollo-Soyuz) space mission in 1975 and were rated very acceptable by the astronauts. It is planned to include this irradiated item in future space flights along with irradiated corned beef and smoked turkey and possibly other irradiated meats, subject to additional evaluations by NASA food acceptance specialists.

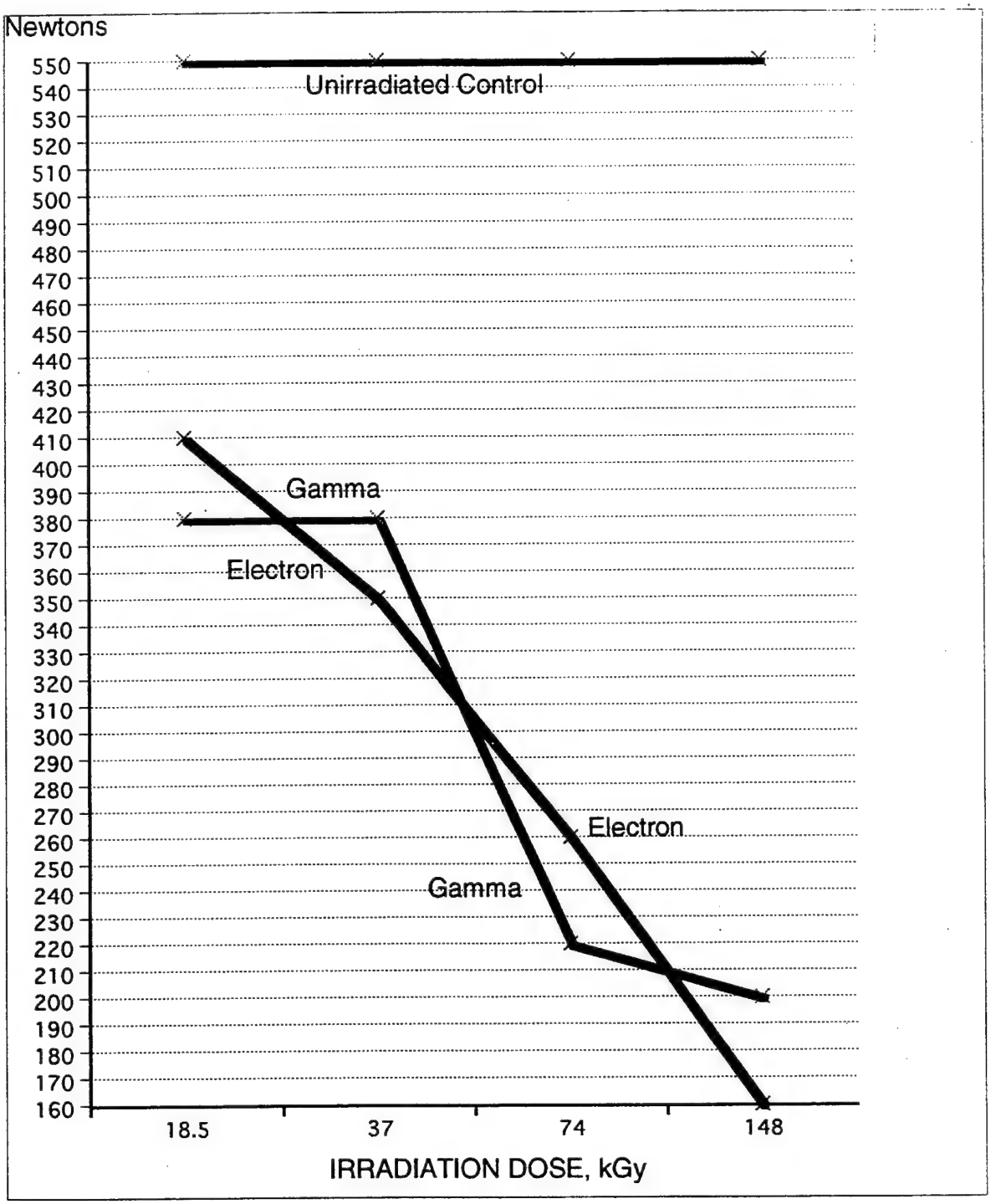

Fig. 1A - SHEAR PRESS SCORES AS FUNCTION OF IRRADIATION DOSE (BEEF LOINS)

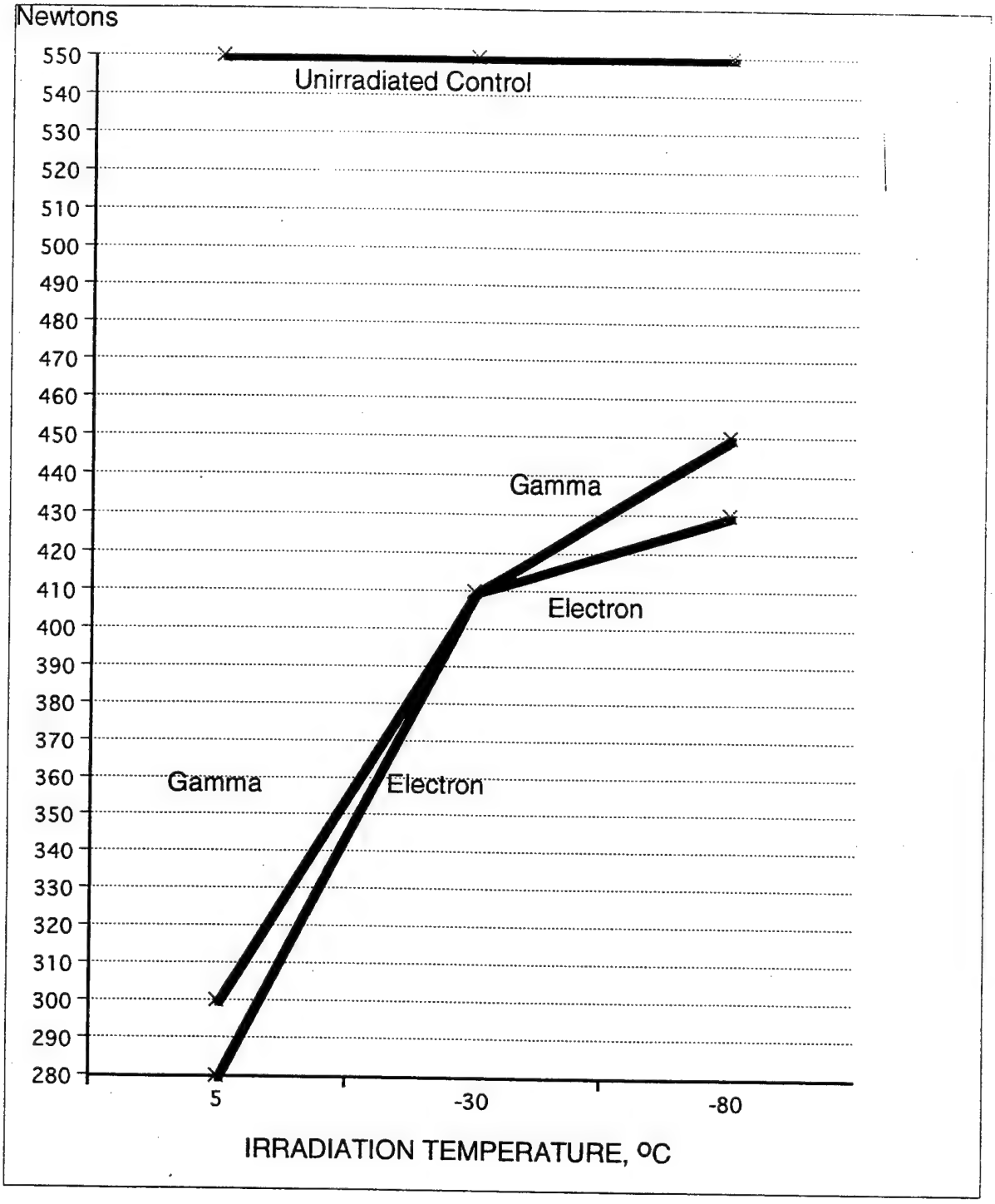

Fig. 1B - SHEAR PRESS SCORES AS FUNCTION OF IRRADIATION TEMPERATURE (BEEF LOINS)

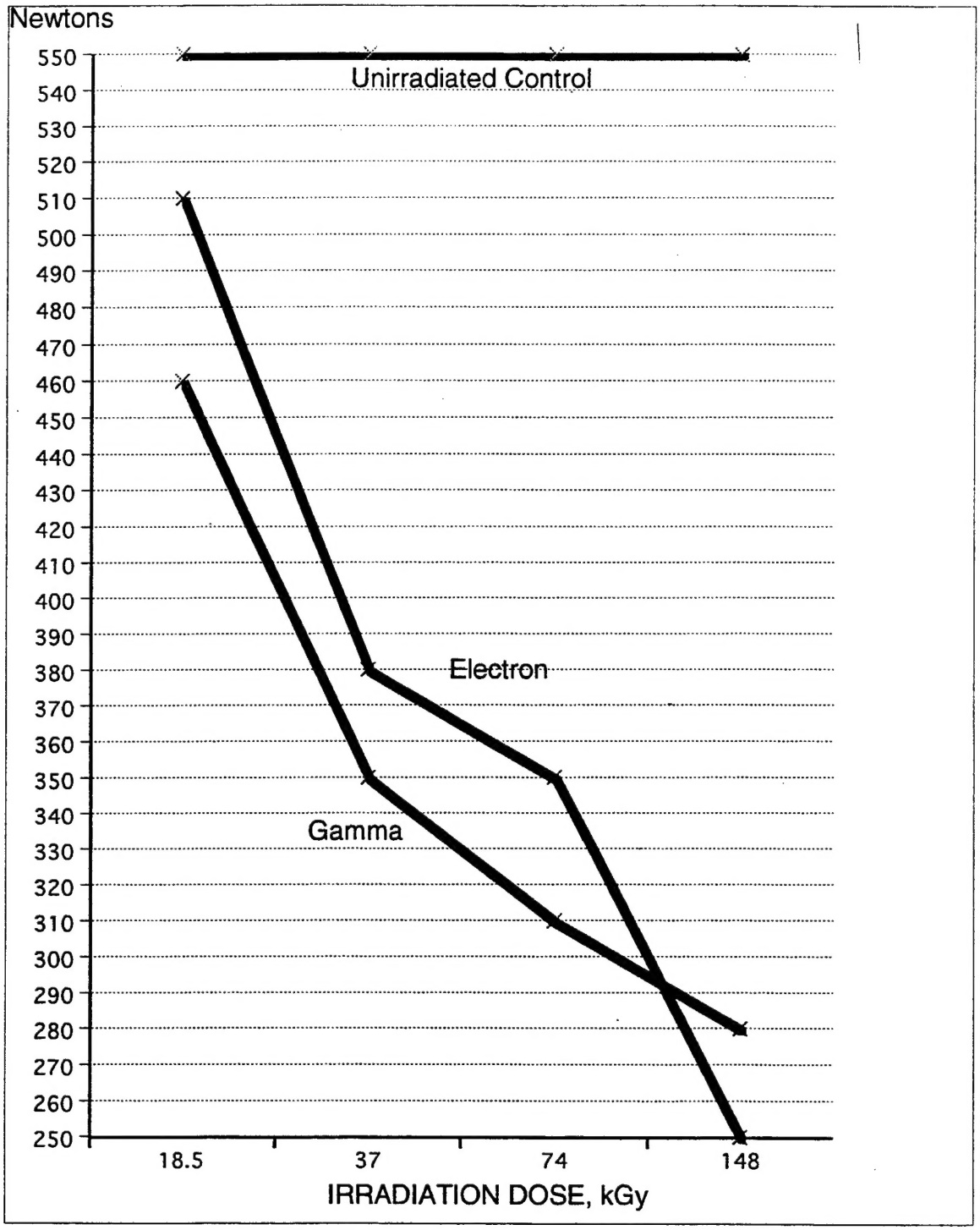

Fig. 2A - SHEAR PRESS SCORES AS FUNCTION OF IRRADIATION DOSE (RESTRUCTURED BEEF STEAKS)

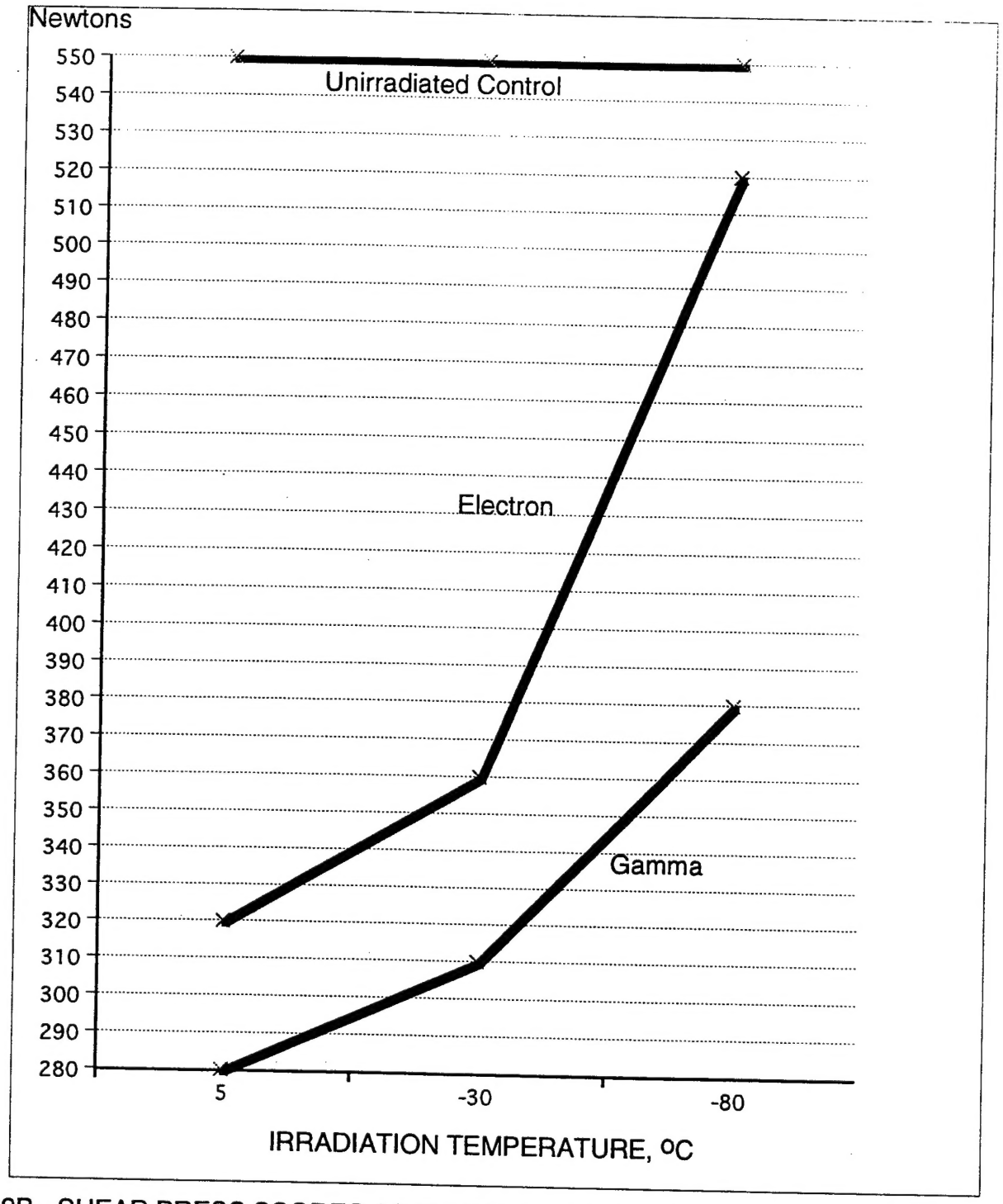

Fig. 2B - SHEAR PRESS SCORES AS FUNCTION OF IRRADIATION TEMPERATURE (RESTRUCTURED BEEF STEAKS)

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